THE SCIENTIFIC MONTHLY

AUGUST, 1922

THE GEOLOGIC EVIDENCE OF EVOLUTION

By Professor EDWARD W. BERRY

THE JOHNS HOPKINS UNIVERSITY

ONE of the outstanding, possibly the only difference between man and the other animals is his ability to profit by the experience and accumulated wisdom of the race, and yet, despite this characteristic, each generation seems to produce its quota of anti-vaccinationists, anti-evolutionists and believers in a flat earth. We may still entertain the hope that the race is becoming more rational when we recall that it has taken about three centuries to convince the Anglo-Saxon and a few other races among the countless millions of the globe that the earth is not flat, so that to-day only the leader of Zion City (Voliva) among leading cosmologists defends the pentateuchal view.

I do not wish to be thought of as sneering at any one's beliefs, and I fully realize that there are a great many earnest Christian men and women who are perturbed at anything that they think, rightly or wrongly, will shake the foundations of their faith, who are puzzled by the present outspoken opposition to evolution, and who wish to know what is the truth. No truer article of faith was ever penned than the motto of the Johns Hopkins University—*Veritas vos liberabit*—and to you seekers after truth I would like to explain away certain misconceptions, before undertaking to show you that the record of earth history is the record of evolution, and not to be disputed by honest people.

Evolution is not a theory of origins, nor an article of scientific faith, but an indisputable fact. We could not teach geology without teaching evolution. One of the difficulties to the layman is the confusion of evolution—the record of the past and present history of organisms—with the various theories that have been proposed to explain its factors or mode of operation. Let me emphasize that evolution, the record, is in an altogether different category from the theories such as Darwinism, Lamarckianism, or any other

ism that has been advanced to explain its working. You may flout all the theories or you may advocate one of a dozen different theories, but this has nothing to do with the history of life. We, in geology, spend much time in going over the history of organisms, but pay but slight attention to the theories—at least in our teaching.

A simple illustration of the once universal and now fortunately less frequent clerical reaction to evolution will make clear what I am driving at. Evolution was regarded as a dangerous heresy, inimical to Christianity, contrary to Genesis, which was regarded as a scientific account of the origin of the earth and its inhabitants. Do these people claim that the hundreds of varieties of horses, dogs, chickens and pigeons go back to the Garden of Eden, or were in Noah's ark, or that all the horticultural varieties of flowers, shrubs and vegetables were in Mother Eve's kitchen garden? *Not at all!* They are more or less familiar with the cattle breeders or the Burbank method of artificial selection. Their objection to evolution rests on the assumption that man is of a different stuff from the brute world—as if they had had no experience with congregations or legislative assemblies. It is the implied collateral relationship with monkeys, and the tradition engendered by medieval art that the devil has a tail that offends their dignity.

The statement that the human species is descended from monkeys is merely polemical obscurantism and the playing on prejudices that started with Bishop Wilberforce—soapy Sam as he was called by some of his contemporaries—and is a sort of Bryanesque smoke screen. As to lineage, man is not at all closely related to the existing monkeys or apes. They are the culmination of different lines of evolution, and this statement is especially true of the monkeys. That their ancestry in the far distant past approximated the human line or indeed may have merged with it millions of years ago in early Tertiary times is quite another matter.

I find nothing in Genesis either for or against evolution. The language, to be sure, is not explicit (dust of the earth), but the special creation of man as opposed to the evolutionary creation is entirely an egoistical interpretation that is supposed, quite wrongly it seems to me, to add dignity to ourselves, and is of a cloth with the idea that the earth is the center of the universe—all the earth (homocentric) centering in man, and all the universe revolving around the earth—man's temporary abode. It is a most curious revelation in the workings of the human mind that so many good people grow indignant over the idea that man was made from a long line of animal ancestry as degrading; and yet who do not

quarrel with the facts that each human starts his or her individual life as a single cell, and during the nine months preceding birth passes through a series of stages that roughly epitomize the main stages of evolution, even to possessing a rudimentary tail like an ape. Five hundred years ago we should have said that embryology was the invention of the devil to test the faith of the elect—exactly a reason that was once advanced to explain the fossils in the rocks. To-day most of us know better, and we find in the truth of creation far more to reverence than in the anthropomorphic deity of the childhood of the races.

In approaching the geological record of evolution, I will state only facts and leave fundamental causes severely alone. The mechanism of evolution we leave to experimental biology, and I do not advocate any theories of explanation. Here is evolution. Here are the myriad of forms that moved across the stage of the past and were the actors in the drama of life. In geology, to borrow a simile from written history or philology, we are dealing with the original documents in so far as they were preserved as fossils, and in their actual order of succession.

In approaching the geological record, the time conception is most important, and I can best illustrate this by a brief recital of the progress of knowledge concerning fossils. It is only in comparatively modern times that fossils have been recognized as the remains of animals and plants that had once been alive. The early Greeks were sane enough to recognize this apparently obvious relationship, and we find Xenophanes, 500 B. C., speculating on the fossils found in the quarries of Syracuse, Sicily. But during the middle ages there was no end to the discussion regarding the nature and origin of fossils. What seems strange in this year of grace may really not have been so strange in the days when the universally held belief was that of spontaneous generation, a flat earth created in six days, and the only past submergence of the land that of Noah's flood. Was it not the same "plastic force" in nature which traced the frost patterns and the moss agate that fashioned the fossils, and was there not every gradation from shells and bones that exactly resemble recent ones to mere stones of similar form and appearance? We now know that the mineral replaces the organic matter of a fossil. Was it strange to have believed three or four hundred years ago that the process was the reverse—from the mineral toward the organic? At any rate many strange theories were evolved to explain the fossils. One tells us that fossil shells were formed on the hills by the influence of the stars. Others called up a stone-making spirit. Others believed that fossils were the models made by the Creator in perfecting his handiwork before

he essayed the task of making living organisms. I am quoting entirely the views of devout churchmen. Others believed that fossils were mere "figured stones," or were the abortive products of the germs of animals and plants that had lost their way in the earth, or that they were the invention of the devil to test the faith. Even after the belief that fossils were the remains of animals and plants had become well established, it was assumed that they had been killed by Noah's flood and stranded on the mountain tops—an interpretation suggested by Martin Luther in 1539 as secular proof of the correctness of the scriptural account. This flood theory found numerous advocates throughout the seventeenth and even far into the eighteenth century. It passed through various phases of opinion. At first, the fossils were regarded as similar to those still living in the vicinity—a natural enough belief when the universal acceptance of the Mosaic cosmology and a world but 6,000 years old is borne in mind. Later, when the differences in the fossils became apparent, it was assumed that they had been swept to Europe and buried by the waters of the flood and represented forms still existing in the tropics. With the progress of knowledge of tropical organisms this last view became untenable, and it was thought that the fossils represented forms that had been exterminated by the flood, and from this it was but a slight step to the once popular belief that there had been no thistles or weeds or noxious insects in the Garden of Eden, that all creation had become base with the fall of man. Gradually it came to be recognized that fossils were not only frequently unlike recent organisms, but that they were very ancient, and not merely antediluvian, but pre-Adamitic—a view first advocated by Blumenbach in 1790. We are still far from a chronology. Granting that fossils were the traces of once living organisms and antedated Adam—what of it? When Guettard (Jean Etienne Guettard, 1715-1786) made one of the first geological maps, it wasn't really a geological map in the modern sense, but a map of what he called mineral bands (like a modern soil map). He had no idea of geological succession or of structure. The credit of recognizing fossils as the modals of creation we owe to the genius of William Smith (1769-1839) and to the orderly arrangement of the Mesozoic rocks of the English Midlands. Smith journeyed about for years in this region, where the succession of fossiliferous strata is an open book. In his work of building canals, roads and drains, he observed that each bed contained fossils, some of which were peculiar to it, and he found that he could recognize the same horizons and the same succession at many different localities.

This important generalization has since been verified and end-

lessly extended. The contained fossils furnish the surest guides to the age of the sedimentary rocks that geology knows. To the biologist these facts have a deeper meaning, for they show that during the vast lapse of time, to be measured in tens or hundreds of millions of years, the living population of the globe has undergone almost continuous change, old simple forms becoming extinct, and newer, more specialized, forms taking their place, the change being, in general, from lower to higher, in other words—evolution.

That God rested from his six days' task of creation just 4004 years B. C. is so absurd that I have yet to meet a person of normal mind who believes in Archbishop Usher's chronology. There have been many attempts to determine the age of the earth in years—calculations of the rate of cooling of molten bodies, the rate of retardation by tidal friction, the thickness of the sedimentary rocks, the amount of dissolved salts added to the oceans by the rivers of the world, the condition of the radium minerals in igneous rocks. All methods contain unknown variables and are merely estimates. A favorite method has been to measure the thickness of a composite section of the sedimentary rocks, for the whole

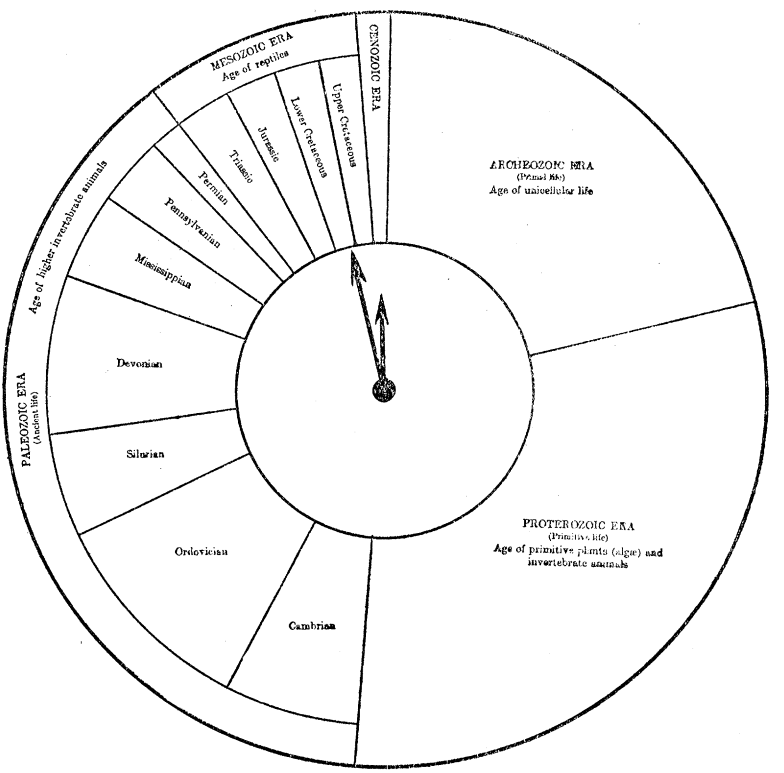

FIG. 1. GEOLOGIC TIME CLOCK

record is not complete in any one section—seas and sediments shifted with the incessant change in geographic pattern. If they had not, we should have such a perfect record of evolution with no missing chapters that we should be able to establish geological time boundaries between rock formations or biological boundaries between animal and plant groups.

The measurement of thicknesses has this advantage, that whereas its results expressed in years are not accurate, its results expressed in relative ratios of duration for the different geological periods are fairly so. I have sought to show the totality of geological time reckoned in this way in the form of the face of a clock in which the dial represents the total thickness of sedimentary rocks divided among the different geological periods in the proper ratios. With this perspective I wish to pass in review in an untechnical way some of the facts of evolution. Obviously, one can not go into details in a brief hour, nor present the links in the chain of evidence, or talk about the septa and sutures of the ammonites, the pygidia of trilobites; or the frontal, parietal, temporal and other bones of the vertebrates.

Show us one species changing into another, and we shall believe in evolution, says the bigot, expecting to see an Alice-through-the-looking-glass transformation of cats into dogs or rabbits into porcupines, not realizing what a species is, or the slowness with which very obvious new characters are acquired as measured in terms of human years. If they had been present through any 70 years of geological time, they would have seen no more evidence of evolution than they see to-day. The first man to see the transformation of species was Waagen,[2] an Austrian geologist and paleontologist, who, in 1869, in the successive layers of fossiliferous Jurassic rocks, observed the minute and inconspicuous changes of form in a definite direction, resulting as they increased in magnitude in the gradual emergence of successive new species of ammonites (Oppelia). These observed grades of difference or nuances (Waagen termed them mutations) are the more gradual and inconspicuous the more abundant the material studied, or the finer our analysis of it. This observed gradual evolution of adaptive characters is quite the opposite of Darwin's theoretical idea of the natural selection of chance variations, and its abundant verification among all groups of fossil organisms wherever an abundance of successive faunas or floras are available for study is one of the reasons why paleontologists have never been strong Darwinists, but

[2] Waagen, Wilhelm Heinrich: Die Formenreihe des Ammonites subradiatus. Versuch einer Paläontologischen Monographie. Geognostisch-Paläontologische Beiträge. Bd. 2, Hft. 2, pp. 179-256, pls. 16-20, November, 1869.

have emphasized the environment as the main stimulus of variation. Discontinuity is observed only in characters where continuity is impossible, as in changes in the number of teeth or vertebra. I could spend days showing you these evolutionary series of trilobites, brachiopods, crinoids, molluscs, etc., but they are not especially convincing without fullness of knowledge and presentation, and are not nearly so impressive to a lay audience as the more obviously discerned, but identical, series among the higher vertebrates. There is probably no group of organisms as ideal for evolutionary studies as are the Ammonites—extinct relatives of the pearly Nautilus. Their shells are preserved in tens of thousands in the Mesozoic and earlier rocks. From the time the embryo formed its first shell until death, each successive stage is preserved in calcite within the enrolled shell. If you would see the size, form and details of ornamentation of a baby, adolescent or mature shell, all you have to do is to break away the outer shell. No other fossils furnish a complete life history with each individual. Moreover, the repetition of phylogeny during ontogeny is beautifully shown, as well as the inheritance of acquired characters, so

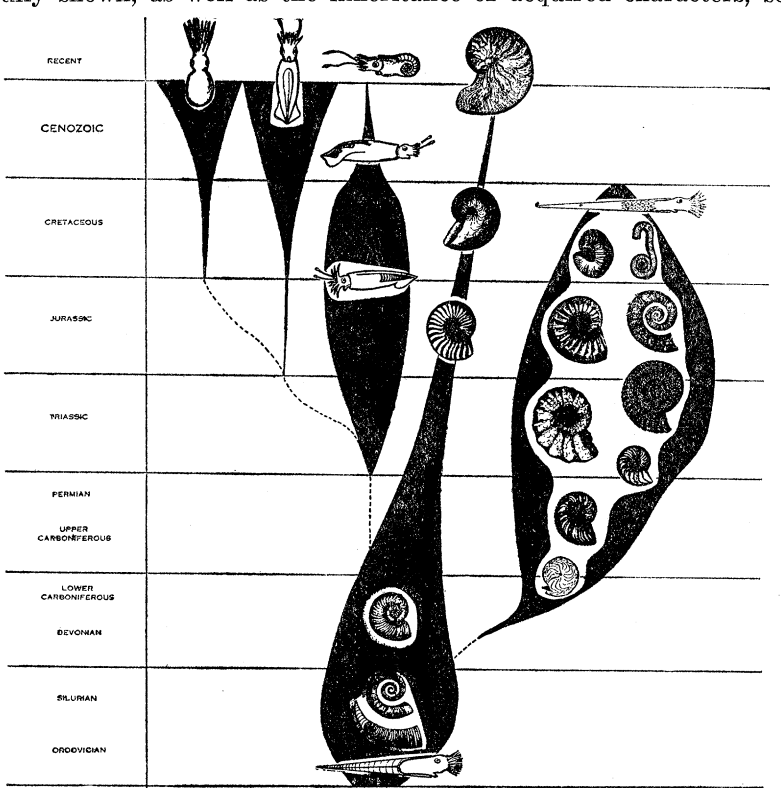

FIG. 2. THE EVOLUTION OF THE CEPHALOD PHYLUM

that we know the ammonite descent much better than we do that of many still existing groups of organisms. The main outlines of the evolution of the Cephalopods, to which group the ammonites belong, is shown in its chronological setting in Figure 2. Observe the gradual transformation of straight camerated shells becoming curved, then loosely coiled, then tightly coiled, giving rise to forms with angulated floors to the living chamber, the parent stock waning with the rise of the daughter stock, and represented to-day by a single living type, the pearly Nautilus. This daughter stock waxing great during Mesozoic times, we know 10,000 different species, gradually reaching overspecialization or racial senility, displayed in the progressive uncoiling and bizarre ornamentation of the shells, and finally passing off the stage altogether. A second main line of descent leads from the ancient Nautilus stock in the direction of animals whose soft parts outgrew their shells, retaining them within the mantle. This second line waxed abundant during Mesozoic time, and then waned in competition with its more perfected progeny, being represented in existing oceans by the single form, Spirula, which in its extreme youth lives in a tiny chambered shell like that of its remote ancestors, but soon outgrows this shell, and for the rest of its life carries this eloquent witness of its ancestry within the hind end of its body. You might remain incredulous before a single Spirula, but when you can trace throughout the records of hundreds of thousands of years the gradual subordination and progressive decrease in relative size of the shell and increase of the soft body, the meaning is unmistakable, and to corroborate the correctness of our reading of history, we have the more modern group of squids and cuttles with all of the morphological features of the Spirula stock, which solved their problem by modifying the now useless shell into an internal axis of support and are otherwise entirely soft bodied and often of large size; and, finally, the latest evolved group—the Octopoda—smaller less active forms, having slight need for the axis of the more elongated and actively swimming squids, have lost all traces of the ancestral shell.

Another great phylum of invertebrate animals (Echinoderma) starfishes, sea urchins and crinoids, have a wonderful abundance of fossil forms and well-ascertained relationships. Their history shows a worm like ancestor developing a plated exoskeleton of many irregular pieces; the progressive reduction in number and the assumption of definite form of these pieces—the radial symmetry impressed by the habit of stalked attachment—the various lines of descent which sought to increase the food gathering mechanism by extending the parts concerned over the test or rais-

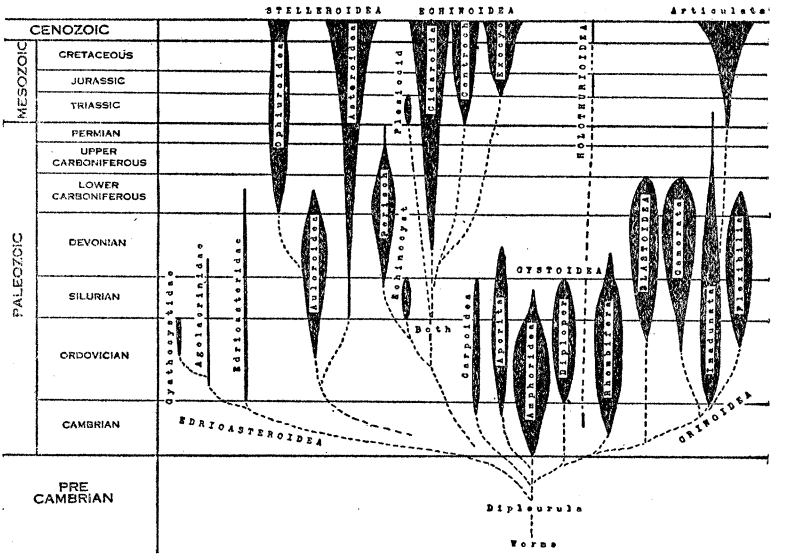

FIG. 3. THE EVOLUTION OF THE ECHINODERM PHYLUM

ing them on long arms—the reversed orientation of the errant urchins and starfishes—the one time dominance of specialized crinoids—the late evolution and present abundance of the free-swimming forms with flexible skeletons—the intermediate or synthetic character of the earlier forms, especially well shown in the Ordovician to Lower Carboniferous ancestors of the starfishes and serpent stars—all afford an excellent chapter in nature's record of evolution.

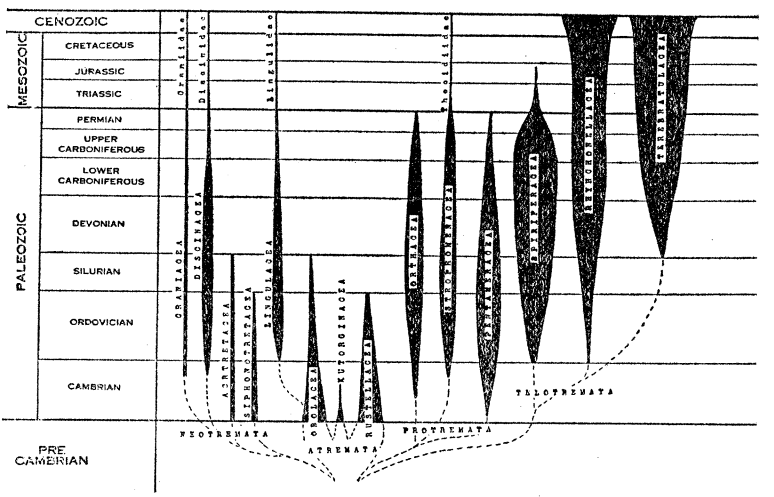

FIG. 4. THE EVOLUTION OF THE BRACHIOPOD PHYLUM

A group of invertebrates unknown to the layman, but immensely important to the paleontologist, whether he be interested merely in chronology or in evolution, is the Brachiopoda—the bivalved lamp shells of the ancients. The stock is very ancient and shows the most intricate series of gradating forms from the ancient hingeless Atremata, long since extinct except for a single family, which in Ordovician times modified its stalk of attachment into a burrowing organ, and from that time to the present has lived on practically unchanged in an unchanging environment of foul mud inimical to higher forms of life, sharing with the similarly reduced representatives of the two other primitive groups a record of unmodified habits or form in an unchanging environment that has enabled them to come down to the present, although all of their early relatives have long since passed off the stage of existence. Contrast the dwindling history of these families as represented by the black of their life lines with the series of forms, each step in whose history we have represented, of those which perfected hinge mechanisms—a protective device, and internal hard parts—loops and spirals for greater efficiency in collecting food and oxygen. We can see these structures grow until at the present time the few unchanged survivors of the more primitive orders are outnumbered fifty to one by the loop-bearing forms which retained the habit of protruding their so-called arms in search of food, whereas the spire-bearing forms that developed along with them in Paleozoic times had their arms fastened to their spiral supports and non-protrusible, and hence faded out of existence in the earlier half of Mesozoic times.

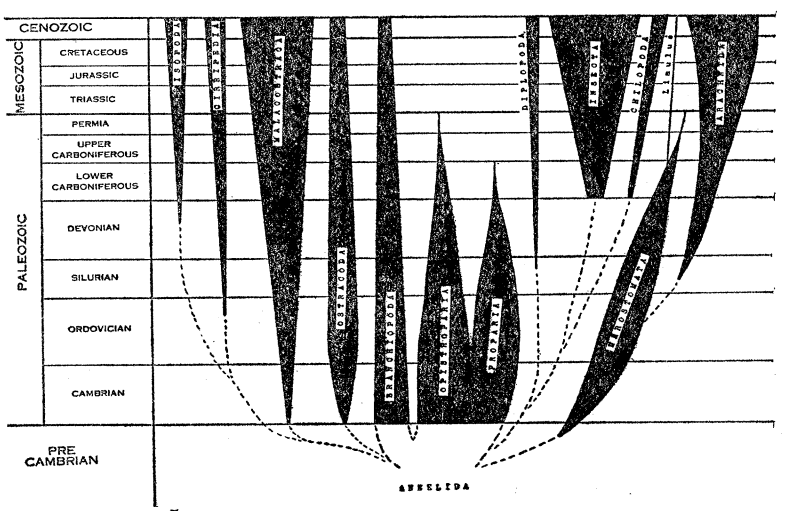

FIG. 5. THE EVOLUTION OF THE ARTHROPOD PHYLUM

A fourth great group is the Arthropoda, embracing the hosts of articulated animals whose relationships are shown, with the early evolution of the aquatic types—trilobites, crustaceans and Limulus-like forms. They exhibit the early efflorescence of the less specialized as to parts, and less protected as to armor—the trilobites; the relative late evolution of their terrestrial descendants—the spiders and centipedes, and the latest appearance of the aerial forms with specialized larval stages—the insects. Most interesting to see displayed among these myriad of diverse forms insects, spiders, crabs and ticks, their community of origin and the impress of their remote trilobite-like ancestry.

Either these myriads of slightly differing forms in progressive or retrogressive series represent evolution, or each slightly changed faunal and floral assemblage represents an independent act of special creation. These are absolutely the only alternatives, and the advocates of special creation, little as they seem to realize it, have to assume a creator, who every few years during a period of hundreds of millions of years mechanically fashioned new sets of organisms. Not only so, but each new set was fashioned surprisingly like their predecessors, sometimes with vestigial, useless or even harmful organs. It seems to me that this only logical application of the special creation hypothesis is a *reductio ad absurdum,* a bare statement of which is sufficient to demonstrate its obvious falsity. I would offer for the religiously inclined Henry Drummond's dictum that evolution was God's method of creation.

The complete epitome of vertebrate evolution showing the range in time and relative abundance deserves a word of comment. I should like the critics of evolution to explain why the most primitive vertebrates appear twice as far back in the record as any of the others, and why the different classes appear in the actual order from the less to the more evolved—from lower to higher—the fish-like amphibians appearing during the Devonian, the reptiles during the Upper Carboniferous, and the two lines to which the latter gave rise, the mammals and birds in the upper Triassic and upper Jurassic, respectively.

Is it not most unfortunate for evolutionary sceptics that the most ancient fossil bird should be one of the best and most spectacular fossils—feathers and all preserved with great fidelity in the fine-grained lithographic stone of Solnhofen—and should represent virtually a modified and partially feathered reptile, 25 per cent. reptile and 75 per cent. bird. About the size of a crow, the head was billess and the jaws were armed with true teeth, the wings had three free-clawed fingers, the tail was long and lizard-like, of 20 vertebræ, with pinnate feathers and not consolidated

with digitate feathers, the hind legs were wide apart and far back, with distinct tibia and fibula as in the reptiles, with the three pelvic bones distinct as in reptiles with no body feathers, the latter on only the wings, legs and tails—with feeble flight and obvious volplaning habits. (Archæopteryx or lizard tailed bird of the upper Jurassic.)

Before taking up man, I have time to consider but two among the many groups of mammals whose history is almost completely known. You doubtless think of elephants in North America only in connection with zoological gardens or circuses, and yet the elephants were a most conspicuous element of the American fauna from the middle Miocene to the end of the Pleistocene, and numerous bones and teeth have been found here in Maryland. They lived in America much longer than has the human race and much longer than the bears which we commonly think of as characteristically American. The elephants were originally immigrants from the old world. They occupy to-day a somewhat isolated position among hoofed mammals and display a curious but readily understandable mixture of specialized and primitive characters. Their specializations are in head and teeth, their conservatism is in body and limbs. To understand their ancestry, we must understand the five or six African and Asian species of the present. Their most obvious feature is the long trunk or proboscis that gives the name Proboscidia to the order. This trunk is simply an elongated nose, although it did not come into existence in the way Kipling relates. Aside from the trunk the tusks mark the elephant. These are simply much modified upper incisor teeth. The dental formula is then $i\frac{1}{0}\ c\frac{0}{0}\ pm\frac{0}{0}\ m\frac{3}{3}$ This is not the whole story of the teeth, however, for, if you examine an elephant's teeth, you will rarely find more than a single immense functional grinder in each jaw ramus—the milk molars, developing serially 1, 2, 3, and followed in turn by the molars 1, 2, 3 during life—the worn ones being pushed forward and out, a contrivance for increasing the elephant's life span, for an animal is only as long lived as its teeth. The mechanics of trunk and tusk support have specialized the head; cranial bones are thickened and lightened, hence the difficulty of shooting an elephant in the brain. The neck is shortened to bring the head weight nearer the withers. The body is long and massive with large shoulder and hip bones. The feet are short and broad with the nail-like hoofs aroumd the edge. Toes are five but not all hoofed (Indian 5 in front, 4 behind; East African 4 in front, 3 behind). Limb adaptations are those common to all heavy animals of other stocks. Most quadrupeds have knee and elbow per-

manently bent. Great weight necessitates the straightening of the limb and individual bones and the shifting of the articular surfaces from an oblique to a right angled position. Weight of tusks causes a shortening and heightening of the skull. Shortening brings the weight arm of the lever nearer the fulcrum at the neck, and heightening lengthens the power arm and affords attachment for the increased musculature. (Modern tusks weighing 239 lbs. each are recorded.) The lengthening of the trunk makes it unnecessary for the mouth to reach the ground for food and water.

The earliest known fossil elephant, only a potential elephant, was of upper Eocene age and comes from near Lake Moeris in the Fayûm, and was consequently christened Moeritherium. It was small and somewhat suggestive of a tapir. The skull was long and narrow, the trunk was merely a snout, the neck was moderately long and the limbs were slender. The teeth were the most significant feature. Formula $i\frac{3}{2}\ c\frac{1}{0}\ pm\frac{3}{3}\ m\frac{3}{3}$ First upper incisor was small and simple, the second was a downwardly directed small tusk. The third and the canine were non-functional and there were 6 grinders, simple and quadritubercular (4 cusps and 2 crests). In the lower jaw the incisors were procumbent. The first long, the second an enamelled tusk with worn chisel edge; the third and canine already gone and 6 grinders. The second stage of elephant evolution was Palæomastodon of the lower Oligocene of the same region. Several species are known, ranging in size from that of a modern tapir to a half grown Indian elephant. Tooth formula $i\frac{1}{1}\ c\frac{0}{0}\ pm\frac{3}{2}\ m\frac{3}{3}$ canines have gone; the incisors are reduced to a single tusk in each jaw ramus, *i. e.*, two upper and two lower tusks. All the grinders are functional, but they have increased in complexity and now consist of six cusps and three crests. The trunk was still short, the head still long and narrow, the limbs heavier, but still relatively light. The elephants now spread into southern Asia and over Europe during the lower Miocene, giving rise to various collateral lines of evolution along their different routes of dispersal. They increased greatly in size and became more elephantine in appearance. They reached North America during the middle Miocene, and these four-tusked forms spread from Nebraska to Florida. The old-world stock shortened the chin and lost the lower pair of tusks during the Pliocene, giving rise to the mastodons and mammoths of the late Pliocene and Pleistocene, which reinvaded North America and ranged southward to the straits of Magellan. Our mastodon survived much later than the European mastodon, and the males sometimes show vestigial tusks in the lower jaw. The mammoth was the contempo-

rary of early man in Europe as the many excellent carvings of the stone age show, and probably also in North America, as somewhat vaguely pictured carved bone and associated flints indicate. They were so common over the northern hemisphere at that time that we have records of 1,635 fossil tusks, averaging 150 lbs., being exported from Siberia in a single year. Between 1820 and 1833, trawlers out of Happisburg, Norfolk, dredged 2,000 elephant molars from the submerged old land of the North Sea. (We had three true elephants in America during the Pleistocene—the Northern or Hairy Mammoth, the Southern or Columbian Mammoth, and the Imperial Mammoth, the latter standing 13 feet at the shoulder.)

The family tree of our noblest of domesticated animals—the horse—has been called the example *de luxe* of evolution, since no animal stock is more completely known or has a more spectacular history. Long domesticated the modern animal is found almost everywhere that man can live, and of many breeds. As wild animals, horses are found only in the Old World in modern times—the arid plains of Central Asia and Africa. There are several species—horses, asses, zebras and quaggas—very uniform in tooth and skeletal characters, but strikingly different in appearance, because of the superficial difference in coloration and in the development of forelock, mane, tail and ears. They differ from all living animals in having a single toe on each foot. Their remotest ancestors were small five-toed plantigrade animals as were all of the earliest mammals. Hosts of fossil species are known, some extinct side lines especially adapted to certain environments, like the small mountain horses or the forest-dwelling and softer ground-inhabiting forms. Others were a part of the progressive line. The earliest known fossil horse you would not recognize as a horse. How do we know it was? By tracing backward step by step from the known. Nearly every stage of this ancestry is now complete, and we are as certain of the remote Tertiary form as we are of the present cart horse. The earliest well-known ancestral horse is the tiny Eohippus or Dawn horse of our early Eocene. It was about the size of a fox terrier, *i. e.*, 11 to 14 inches high, with a short neck, long body, arched back, short legs and small teeth. The front feet had 4 functional toes, and a splint representing the first or thumb. The hind feet had 3 functional and 2 splints representing the first and fifth. It is significant that at that time the ancestral horse line is so generalized that a layman could not distinguish it from the contemporaneous ancestral rhinoceroses or tapirs.

The second-stage Protorohippus of the middle Eocene was

about the size and proportions of a whippet hound. The thumb splint had now disappeared from the front foot, and the little finger splint from the hind foot. The weight was beginning to center on the middle toe, but it required two or three million years more to completely suppress the lateral toes. If there were time, we might pass in review each stage of horse evolution—the Epihippus of the upper Eocene, the Mesohippus of the Oligocene, about the size of a sheep, the Miocene, Protohippus, Pliohippus, Neohipparion, etc. The upper Miocene Protohippus is in the direct line and may be briefly characterized. About 40 inches high, longer head, longer teeth, deeper jaws, shortened body, longer legs and feet, only the third toe normally reaching the ground, but the second and fourth were complete "dew claws" and helped to support the weight on soft ground. There were many varieties of three-toed horses, and in the late Tertiary they had spread pretty well over the world, being found in South America, Europe and Asia, as well as in North America. By Pleistocene time the horses had become monodactyl, varied, abundant and wide ranging. So countless were the herds that the Sheridan formation of the West was long known as the Equus beds from the abundance of their fossil remains. When, however, America was discovered, horses had become extinct in the western hemisphere as well as in native tradition, although their bones are found associated with flint implements, pottery and fire refuse. They appear to have first been domesticated during the Neolithic, that is about 7000 B. C. in Europe, but probably at a much earlier date in Asia. Our modern work horse is descended directly from the European Neolithic horse, which was much like the Celtic pony. Descendants of this low-bred primitive race were distributed over Eurasia, where they are still represented by the Norwegian and Mongolian ponies. All the earlier horses of written history belonged to this type. It was improved by importations from Libya—the Arabs, for example, getting stallions and brood mares from Barbary, where the stock had suffered no ill effects during the Pleistocene glaciation, there having been no severity of climate in northern Africa. The course of evolution in the horses was not confined to the feet. It may be summarized as follows:

Along with the disappearance of side toes went increase in length of leg and foot, especially the distal portion. Increased length of the lower leg and foot increased length of stride and, as the chief muscles are in the upper leg, the center of gravity was changed very little, consequently the swing was about as rapid but mechanical strain was greatly increased, so that strengthening at the expense of flexibility by consolidation of the lower leg and

arm bones and conversion of ball and socket into pulley joints (ginglymoid) occurred. Lengthening of limbs for speed in grazing animals necessitates lengthening of the neck. Loss of toes was a hard ground adaptation for speed. The lengthening of the teeth which caused the deepening of the jaws was an adaptation for hard food and ensured more thorough mastication and a longer life span. Increase in size, although demanding an increased food supply, is a better defence against enemies or competitors. The evolution of the horse was from forest and swamp to grassy plains and went hand in hand with the evolution of the environment. Since monkeys are unaccountably not fashionable and we are very fond of horses here in Maryland, I show you for comparison a skeleton of a modern horse and man. Not only in the structure of all his physical parts, bone for bone, muscle for muscle, and nerve for nerve, is man fundamentally like the other mammals, but his specific organic functions are identical. We have the same diseases; we are similarly affected by the same drugs—in fact the whole wonderful advance of physiology and experimental medicine is built up on this truism. Have you ever thought of the countless generations of meat-eating humans involved in the specialization of the two human tape worms—the one passing its intermediate stage in beef and the other in pork and of which man alone is the host of the adult stage. The pre-humans were not meat-eaters, and we should not fail to take into account the improvement in nutrition in shortening the digestive processes and the stimulating properties of the proteins and their split products that a change in diet gave our ancestors the energy for other things.

I have already mentioned the remoteness of man's relationship with the existing monkeys and apes. Unfortunately, we have but slight knowledge of the earlier stages which remain hidden in the unexplored regions of Asia and Africa, to which much evidence points as the original homes of a majority of the mammalian stocks that appeared in Europe and North America during the Tertiary. But we know much of our less remote fossil ancestors. Evidences of their slowly advancing skill in the fashioning of weapons and implements, in the discovery of the bow and the uses of fire are innumerable, and their skeletal remains are found over a period estimated at from 250,000 to over a million years. We know at least two, perhaps three extinct genera of men and at least five distinct human species. All the existing races of man—white, black, red and yellow—belong to the single zoological species which we modestly call *Homo sapiens*. I should say that our knowledge of the exact stages between non-human ape-like animals and man is as complete as was the knowledge of the evolution of the horse

at the time of the founding of this university when Huxley lectured on the evolution of the horse. At the present rate of discovery (Piltdown man in 1911, Foxhall man in 1919 and Broken Hill man in 1920), another generation will not pass before the story is complete.

Before relating what we now know of this story, I should like to refer to how we arrive at estimates of age in this part of the geological column—estimates which are as exact as the earlier dates of what is called the historic period. During geologic time immediately preceding the present there is conclusive evidence of a mantle of ice spreading over northwestern Europe and northern North America. This was not a single episode but a long enduring succession of glacial stages and milder interglacial stages—some of which were much longer than the time that has elapsed since the last ice sheet shrunk away from the Baltic or from the valley of the St. Lawrence. Naturally the deposits and moraines of the last ice sheet are fresher and less disturbed than the similar traces of the earlier ice sheets. By counting the annual layers in the clays in the wake of the shrinking ice of the last glaciation, we can trace and date its gradual withdrawal from the plains of Germany across the Baltic to the Scandinavian uplands, and the more broken clay layers in the valleys of the Connecticut, Hudson and Champlain give the story for this country. Using this period of time as a unit, we calculate from a variety of criteria the duration of the earlier glacial and interglacial stages. The oldest known man-like animal comes from distant Java and dates from the beginning of the Pleistocene, or from 250,000 to 1,000,000 years ago, or more precisely, twenty-five times as long ago as the interval since the last ice sheet extended across Long and Staten Islands here in the eastern United States. Evidence of human, or if you prefer so to call it, pre-human, industry in the form of rudely chipped flints and a knowledge of fire occur still earlier, and if the recent discovery of the Foxhall man in East Anglia is properly dated, we shall have unmistakable evidence of man in the late Pliocene. Our knowledge of the ape man of Java is on a sounder footing. First of all, he came from Asia along with the greater part of the considerable variety of animals and plants that are found fossil with him. The motive power was the less hospitable climates in Asia resulting from the gradual uplifting of its great mountain areas in the late Tertiary. The fauna and flora including the ape man drifted to the southeast down the broad valleys that at that time of emergence made a single land mass of the Malayan region. The anatomical features of the ape man are technical. Our interest centers on the brain case and the fact that

he was a ground inhabiting biped and not arboreal. The cranial capacity has been variously estimated between 850 and 950 cc as compared with 1,300 to 1,700 of the Neanderthal man of the third Interglacial period, or 650 cc, the greatest ape brain in the gorilla, which has twice the body weight of a man. The lower frontal-lobe region of this brain case shows conclusively that Pithecanthropus possessed speech—not sounds or signals expressive of emotional states, but that he was capable of transmitting ideas and information. In the painstaking models of McGregor, he has managed to superimpose on the obvious inheritance of the brute a look of fleeting intelligence and a dumb prophetic gaze that gives promise of the great things of the then far off future, and I confess to feeling a more tremendous thrill in the contemplation of that empty brain case than any other fossil has invoked.

A long gap in the record brings us to Sussex, England, and Eoanthropus or Dawn man of Piltdown. Discovered in 1911 the usual ignorance resulted in the destruction of most of the skeleton, as it did also in the wonderfully interesting find in the Broken Hill Mine of Rhodesia, so that only a few fragments of skull, 3 teeth, and a portion of the jaw were saved. Subsequently more fragments of other individuals have rewarded the most patient and painstaking search. If there is a wise Providence overhanging the world it is certainly watching over the paleontologists instead of their critics, which is rather surprising if paleontologists are as bad as they are sometimes painted, for these later finds are exactly the pieces needed to supplement the earlier, and to justify Smith Woodward's conclusions. The Piltdown man probably lived during the long and warm second Interglacial period. With him are found very primitive worked flints of the type known as pre-Chellean, together with bones of the rhinoceros, hippopotamus, beaver and deer. The skull is about twice as thick as a modern and 50 per cent. thicker than a Neanderthal skull. Its capacity was about 1,300cc. The jaws are protruding, the chin receding, the nose flattened and the canine teeth very prominent; in fact, although the skull and brain are essentially human and denote the power of speech, the jaws and teeth are much like those of a young chimpanzee, as are certain muscular attachments of the neck and temporal regions.

About the same age as the Piltdown man is the so-called Heidelberg man, based on a single jaw found in 1907 associated with a large fauna at the base of the Mauer sands, 79 feet below the surface. This jaw is exceedingly massive with receding chin, but human dentition, and is generally regarded as merely an extinct species *Homo heidelbergensis,* although some students would erect a distinct genus, Paleonthropus, for its reception. It seems clearly

to foreshadow the Neanderthal race of the third Interglacial period. Passing over implements representing the evolution of human industry and confining our attention to actual human bones, we must now jump from the time of the Piltdown and Heidelberg men over a blank interval, estimated at from one to two hundred thousand years, to the Neanderthal race. I say race advisedly, because some hostile critics have waxed humorous or satirical over the type skull-cap found in the Neander valley near Düsseldorf, as if that were the whole story. The earliest find of this race was a female skull found at Gibraltar in a cave in 1848, but the significance of which was not recognized until 1887. The Neander skull-cap with thigh bones and other fragments was discovered in 1856, and their description was received with indifference even by Darwin and Huxley, and it was not until a generation later, when two complete skeletons were found at Spy near Dinant in Belgium, 1887, that recognition of their significance became general. The appearance of this race in western Europe was contemporaneous with the wane of the last warm forest and meadow fauna of the Pleistocene and with the invasion of animals heralding the approach of the fourth glaciation. Hence the Neanderthal race dwelt in caves. Wells writes picturesquely, but not especially accurately, of their jackal-like habits, but the Neanderthalers were hardy, and appear to have utilized the bison, wild cattle, horse and deer for food, ousting cave bear and cave hyenas—the successive layers in the caves often tell an eloquent story of the struggles between man and beast for possession. Fire played its part and old hearths are abundantly preserved. Spears and throwing stones appear to have been the weapons used. The abundance of skeletons of this race is due to their cave habit and hence their better chance for preservation. Over an interval of something like 50,000 years, if not much longer, preceding Neanderthal times, we have abundant evidence of human industry in the pre-Chellean and Chellean cultures represented by flint implements, but these open-air nomads either threw their dead to the hyenas or buried them in the river terraces on which they dwelt, where the chances of preservation and fossilization were remote.

Homo neanderthalensis, primigenius or *mousteriensis* as it has been called, has been discovered at over twenty different localities. Skeletons of men, women and children and of many individuals have been collected, so that the earlier critics of the type material who pronounced them merely pathological, *i. e.*, a diseased modern man, are completely and absolutely refuted. In many of their important features this race was more ape-like than human, but their teeth were decidedly human; they possessed the power of speech,

fashioned skins and weapons, were skilled in the use of fire, and practised ceremonial burial, placing implements with their dead, the first appearance in the geological record of a belief in a future existence, so that we can not cut them off from us and say they were apes and not men. Let us get a good picture of this race that lived in Europe longer than have the Anglo-Saxons. They were short and thickset—the tallest skeleton indicates a height of 5 feet, 5½ inches; with very broad shoulders and muscular robust torso, big hands, short fingers, and not entirely perfected thumb joints. They were clumsy on foot, with ape-like legs, in that the shin is relatively short and the thigh long (shin 76 per cent. of thigh). Their knees were habitually bent, and they were squatters instead of sitters when resting or working, as shown by the facets on the ankle bone (astragulus). The forearm was relatively short, like the modern Eskimos, Lapps and Bushmen. That they were far removed from contemporary apes is shown by their arms being but 68 per cent. the length of their legs. In apes the reverse prevails—the chimpanzee's arm is 104 per cent. the leg length. The position of the foramen magnum, and the neck vertebra indicate stooped shoulders with the head held well forward, and a spinal column curved like that of a modern baby. The head was massive, with deep face, retreating forehead from heavy overhanging brows (platycephalic), with broad flat nose, long upper lip, prognathous jaws and receding chin. The skull was thick, but capacious. The jaw was similar to, but less massive than, that of the Heidelberg man of the second Interglacial. Let me point out that if you should find a modern skull with some of the ape-like features of the Neanderthal skull, it would prove nothing. Some of these ape-like features do occur in recent rare individuals of the lower races—they are all present in the Neanderthal skulls that have been discovered. I have said that the skull was capacious—the limits of variation are 1,300 to 1,700 cc (existing man, 950 to 2,020 cc). The size of the Neanderthal brain was therefore entirely human, but I need not emphasize that a large head does not necessarily offer anything except a field for tonsorial art, and what critics fail to take into account is that the Neanderthal brain, although it had quantity, lacked quality—its proportions were decidedly different from a modern brain—those parts concerned with the higher faculties were less developed and with simpler convolutions—this is not inference, but is based on the actual configuration of the interior of the brain case (we even know that they were right-handed). Over 50 sites of Neanderthal industry are known in western Europe (see map) and their implements increased in variety and improved in technique as the years passed, but not to any remarkable degree.

Some anthropologists hold that the Neanderthal race is represented by the Brünn and Piedmont races of the upper Paleolithic, others that they were exterminated by the arrival in western Europe of a new race from Asia about 25,000 years ago. This progressive race of *Homo sapiens,* the same species as ourselves, appears to have come from Asia Minor through Tunis into Spain, and perhaps along the northern shores of the Mediterranean as well. Their successive cultures are known as the Aurignacian, Solutrian, Magdalenian and Azilian, and the development of their industry and art has been traced with the most detailed precision. They were hunters, and followed in the trail of the wild ass, Elasmothere, steppe horse and various other Asiatic immigrants. Associated with fourteen Cro Magnons skeletons in the Grotto on the Riviera near Mentone are two negroid skeletons. (I will not stop to describe this negroid Grimaldi type.) The fourth Glacial period had not yet closed when the Cro-Magnons apeared in Europe, but the climate was dryer—the summer temperate, but the winters severe. Most of the stations where their remains have been discovered were in caves or rock shelters, but several open camps have been discovered, as at Solutré which was probably a summer assembling of hunters. This remarkable race was tall, the average height 6 ft. 1½ inches, with large chest, relatively long legs, remarkable lengthening of the forearm and shin, wide short face, prominent cheek bones, narrow pointed chin, narrow skull, aquiline nose and shallow orbits. They were vigorous and fleet-footed, practiced ceremonial burial, had much improved implements including the bow and arrow and stone lamps, with brains 1,500 to 1,880 cc. They show an appreciation of animals and have been called the Greeks of the old stone age because of their art, which included drawing, engraving, paintings and bas reliefs on cavern walls and floors, and the carving of soapstone, bone and ivory. Their history shows fluctuations in art and industry, in particular their flint workmanship declined with the introduction of bone implements. During the climatic fluctuations concerned with the oscillations of the shrinking glaciers and concomitant geographic changes, both their culture and physical vigor show a decline. Their history covers a period of from 10,000 to 15,000 years, and during this time there probably was some intermixture of other blood. Disharmonic skulls, *i. e.,* broad face and narrow skull, are still found in the Dordogne and at a few other localities and near by is the primitive agglutinative language of the Basques. Some conclude that these represent late survivals of the Cro-Magnon race. They were followed by fishing races and the first broad headed types, the Maglemose culture (possibly Teutonic) around the Baltic, the Mediterranean (known as the Tardenoisian), and

the Alpine (Furfooz Grenelle) along the Danube (painted pebbles). This was from 7,000 to 10,000 years ago, and the so-called Campignian culture of this time is transitional to the Neolithic or New Stone Age of polished stone.

The rest of the history belongs more to Anthropology and Archeology. The Robenhausian culture of the Swiss and other lake dwellings about 7000 B. C. shows permanent dwellings, domestication of animals and cultivation of crops with use of pottery: the Copper Age extended from 3000 to 2000 B. C.; the Bronze Age in Europe from about 2000 to 1000 B. C., in Orient 4000 to 1800 B. C.; the Iron Age (earlier or Hallstatt culture) in Europe from 1000 to 500 B. C., in the Orient from 1800 to 1000; and the latter Iron Age from 500 B. C. to Roman times in Europe.[1]

Note the cumulative rapidity of the advance as compared with slowness of change in earlier stages.

Although very much remains to be discovered we know enough to assure the layman that man has had a long evolutionary history extending over tens if not hundreds of thousands of years. Does this knowledge breed cynicism and irresponsibility. What answer does science give on this point? Since late Paleolithic time, *i. e.*, toward the close of the Old Stone age, 25,000 years ago, man's evolution biologically has been slight and to some extent retrograde. Skull bones and teeth have changed but little. It was during this period of slight physical change that our race has made the most astonishing progress, and the hope is natural that there is no limit to the betterment of the race by the exercise of wisdom, altruism and idealism—the spiritual graces if you choose so to call them.

[1] Figures from Obermaier.